

THE CLAIMS

What is claimed is:

1. A sacrificial silicon-containing layer etching composition, comprising a supercritical fluid (SCF), at least one co-solvent, at least one etchant species, and optionally at least one surfactant.
2. The composition of claim 1, wherein the SCF comprises a SCF species selected from the group consisting of carbon dioxide, oxygen, argon, krypton, xenon, and ammonia.
3. The composition of claim 1, wherein the SCF comprises carbon dioxide.
4. The composition of claim 1, wherein the co-solvent comprises at least one C₁-C₆ alcohol.
5. The composition of claim 1, wherein the co-solvent comprises methanol.
6. The composition of claim 1, wherein the co-solvent comprises isopropanol.
7. The composition of claim 1, wherein the sacrificial silicon-containing layer comprises a silicon-containing species selected from the group consisting of silicon oxide and silicon nitride.
8. The composition of claim 7, wherein the etchant species comprises at least one bifluoride compound selected from the group consisting of ammonium bifluoride, tetraalkylammonium difluoride ((R)₄NHF₂), and alkyl phosphonium difluorides ((R)₄PHF₂), wherein R is a C₁-C₄ alkyl group.
9. The composition of claim 7, wherein the etchant species comprises ammonium bifluoride.

10. The composition of claim 7, wherein the etchant species comprises tetraalkylammonium difluoride $((R)_4NHF_2)$, wherein R is a C_1 - C_4 alkyl group.
11. The composition of claim 7, wherein the etchant species comprises alkyl phosphonium difluoride $((R)_4PHF_2)$, wherein R is a C_1 - C_4 alkyl group.
12. The composition of claim 7, wherein the surfactant comprises at least one nonionic or anionic surfactant, or a combination thereof.
13. The composition of claim 12, wherein the nonionic surfactant is selected from the group consisting of fluoroalkyl surfactants, polyethylene glycols, polypropylene glycols, polyethylene ethers, polypropylene glycol ethers, carboxylic acid salts, dodecylbenzenesulfonic acid, dodecylbenzenesulfonic salts, polyacrylate polymers, dinonylphenyl polyoxyethylene, silicone polymers, modified silicone polymers, acetylenic diols, modified acetylenic diols, alkylammonium salts, modified alkylammonium salts, and combinations comprising at least one of the foregoing.
14. The composition of claim 12, wherein the nonionic surfactant comprises a modified acetylenic diol.
15. The composition of claim 7, wherein the etching composition comprises about 75.0 wt % to about 99.5 wt % SCF, about 0.3 wt % to about 22.5 wt % co-solvent, about 0.01 wt % to about 5.0 wt % etchant species, and about 0.01 wt % to about 5.0 wt % surfactant, based on the total weight of the composition.
16. The composition of claim 1, wherein the sacrificial silicon-containing layer consists essentially of silicon.
17. The composition of claim 16, wherein the etchant species is XeF_2 .

18. The composition of claim 16, wherein the etching composition comprises about 75.0 wt % to about 99.5 wt % SCF, about 0.3 wt % to about 22.5 wt % co-solvent, about 0.01 wt % to about 5.0 wt % etchant species, based on the total weight of the composition.
19. A method of removing silicon-containing substances from a substrate having same thereon, said method comprising contacting the substrate with a SCF-based composition comprising a SCF, at least one co-solvent, at least one etchant species, and optionally at least one surfactant, for sufficient time and under sufficient contacting conditions to remove the silicon-containing substances from the substrate.
20. The method of claim 19, wherein the SCF is selected from the group consisting of carbon dioxide, oxygen, argon, krypton, xenon, and ammonia.
21. The method of claim 19, wherein the SCF is carbon dioxide.
22. The method of claim 19, wherein the contacting conditions comprise pressures in a range of from about 1400 to about 4400 psi.
23. The method of claim 19, wherein said contacting time is in a range of from about 30 seconds to about 30 minutes.
24. The method of claim 19, wherein the co-solvent comprises at least one C₁-C₆ alcohol.
25. The method of claim 19, wherein the co-solvent comprises methanol.
26. The method of claim 19, wherein the co-solvent comprises isopropanol (IPA).
27. The method of claim 19, wherein the silicon-containing substance is selected from the group consisting of silicon oxide and silicon nitride.

28. The method of claim 27, wherein the etchant species comprises at least one bifluoride compound selected from the group consisting of ammonium bifluoride, tetraalkylammonium difluoride $((R)_4NHF_2)$, and alkyl phosphonium difluoride $((R_4PHF_2)$, wherein R is a C₁-C₄ alkyl group.
29. The method of claim 27, wherein the etchant species comprises ammonium bifluoride.
30. The method of claim 27, wherein the surfactant comprises at least one nonionic or anionic surfactant, or a combination thereof.
31. The method of claim 30, wherein the nonionic surfactant is selected from the group consisting of fluoroalkyl surfactants, polyethylene glycols, polypropylene glycols, polyethylene ethers, polypropylene glycol ethers, carboxylic acid salts, dodecylbenzenesulfonic acid, dodecylbenzenesulfonic salts, polyacrylate polymers, dinonylphenyl polyoxyethylene, silicone polymers, modified silicone polymers, acetylenic diols, modified acetylenic diols, alkylammonium salts, modified alkylammonium salts, and combinations comprising at least one of the foregoing.
32. The method of claim 27, wherein the SCF-based composition comprises about 75.0 wt % to about 99.5 wt % SCF, about 0.3 wt % to about 22.5 wt % co-solvent, about 0.01 wt % to about 5.0 wt % etchant species, and about 0.01 wt % to about 5.0 wt % surfactant, based on the total weight of the composition.
33. The method of claim 19, wherein the silicon-containing substance is selected from the group consisting of silicon, post-ash residue and post-etch residue.
34. The method of claim 33, wherein the etchant species is XeF_2 .
35. The method of claim 33, further comprising dehydrating the substrate prior to contacting the substrate with the SCF-based composition.

36. The method of claim 31, wherein the SCF-based composition comprises about 75.0 wt % to about 99.5 wt % SCF, about 0.3 wt % to about 22.5 wt % co-solvent, about 0.01 wt % to about 5.0 wt % etchant species, based on the total weight of the composition.

37. The method of claim 19, wherein the contacting step comprises an etching cycle including (i) dynamic flow contacting of the etching composition with the silicon-containing substance, and/or (ii) static soaking contacting of the etching composition with the silicon-containing substance.

38. The method of claim 37, wherein said etching cycle comprises alternatingly and repetitively carrying out dynamic flow contacting and static soaking contacting of the silicon-containing substance.

39. The method of claim 19, further comprising the step of washing the substrate, at a region at which the silicon-containing substance has been removed, with a SCF/methanol/deionized water wash solution in a first washing step, and with a SCF in a second washing step, to remove residual precipitated chemical additives in said first washing step, and to remove residual precipitated chemical additives and/or residual alcohol in said second washing step.

40. The method of claim 39, wherein the SCF is SCCO_2 .